Littoral Environment Visualization Tool

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LONG-TERM GOALS

The focus of critical U.S. programs on Homeland Security and Homeland Defense applications, and on the brown water navies of potential adversaries elicits a need for understanding and visualizing the near-shore land and maritime environments. Being able to view existing and forecasted animations of littoral zones as impacted by changing environmental elements is important for successful planning and execution of a myriad of operations. As a minimum these operations include: transfer of cargo from large sealift vessels across a beach or un-improved port, terrorist containment, debris/trash collection, equipment/personnel transport, fire fighting, beach washing, emergency fuel transfer, emergency lightering and littoral warfare.

An ability to view simulations of the littoral zone will greatly increase the likelihood of mission success for these and other types of operations.

The goal of this project is to develop a windows application that will provide a near real-time visual depiction of wave, wind, or other environmental elements' impact on the littoral environment that can be used as an aid to decision makers in their planning/response efforts.

OBJECTIVES

To achieve our goal we will use our latest commercially available PC-based military simulation. Our commercial off-the-shelf (COTS) naval strategy simulation, *Sonalysts Combat Simulations – Dangerous Waters®*, includes high fidelity 3D micro-simulations of subsurface, surface, and air platforms that also include environmental characteristics such as day/night, currents, wind and stormy weather. The primary focus of this simulation is in the deep water environment. We will modify this engine as necessary to provide a realistic animation of the shallow water environment that exists within the littoral zone.

We intend to show the feasibility of performing this shallow water visualization process through a proof of concept application developed during this Phase I period of nine months. This proof of concept will demonstrate a computer-based tool capable of providing fairly rapid rendering and realistic visualization of a littoral environment that is composed of varying elements such as wind speed and direction, wave height, periodicity, and direction.

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SCS – Dangerous Waters Commercial Military Simulation Engine
Used to Develop Shallow Water Visualization

APPROACH

During this Phase I we will concentrate on performing research into the type of data that characterizes the environment of the littoral zone and its availability for input into a proof of concept application. We will provide an early determination on the viability of using our commercially available simulation to provide a real-time rapid response to changing parameters within the visual representation of the littoral zone.

Our team consists of a principal investigator, 2 software engineers and a Graphic Artist/2D-3D Model Development Specialist.

Research was conducted in the following activities by the software engineers and the principal investigator:

- *Gain an understanding of the computational effort required for varying degrees of visualization detail and realism.* We researched implementation methods for littoral element features such as water surface, underwater, terrain, air and objects such as vessel traffic and navigation aids. We estimated the level of effort and computational power required to provide a highly visual and realistic view of the littoral environment.

- *Evaluate forecast model data to determine sufficiency for providing realistic animations.* We investigated the availability of real-time and forecast data types from a variety of environmental models that could be used as inputs to our naval simulation engine. These inputs included such elements as: tides (water level), currents, wind speed and direction, water temperature, air temperature, air pressure, and wave heights (deep water).

The Principal Investigator performed a web search to obtain sites providing a visual picture of near shore areas that are accompanied by environmental data. When an area was selected the Graphic Artist/2D and 3D Model Development Specialist ensured the static (non-wave) areas of the selected views were reflected as accurately as possible in the picture produced by the simulation engine.

- *Determine ability of animation to realistically reflect changes to the littoral environment.* We researched the availability of weather data for actual photographs of littoral areas represented by climatological data. This data will be used as input into the simulation, along with photos of the actual area represented by the data. The photos can be compared with the simulation's visualization of the same area.

The software engineers modified our commercial simulation to provide an application to show our concept.

- *Demonstrate Modeling Tool Proof of Concept.* A key assessment criterion for this tool will be the ability to show a realistic real-time simulation of the littoral environment. The tool will make use of our commercial simulation engine and also be capable of visualizing the modification of environmental elements within the littoral zone.

WORK COMPLETED

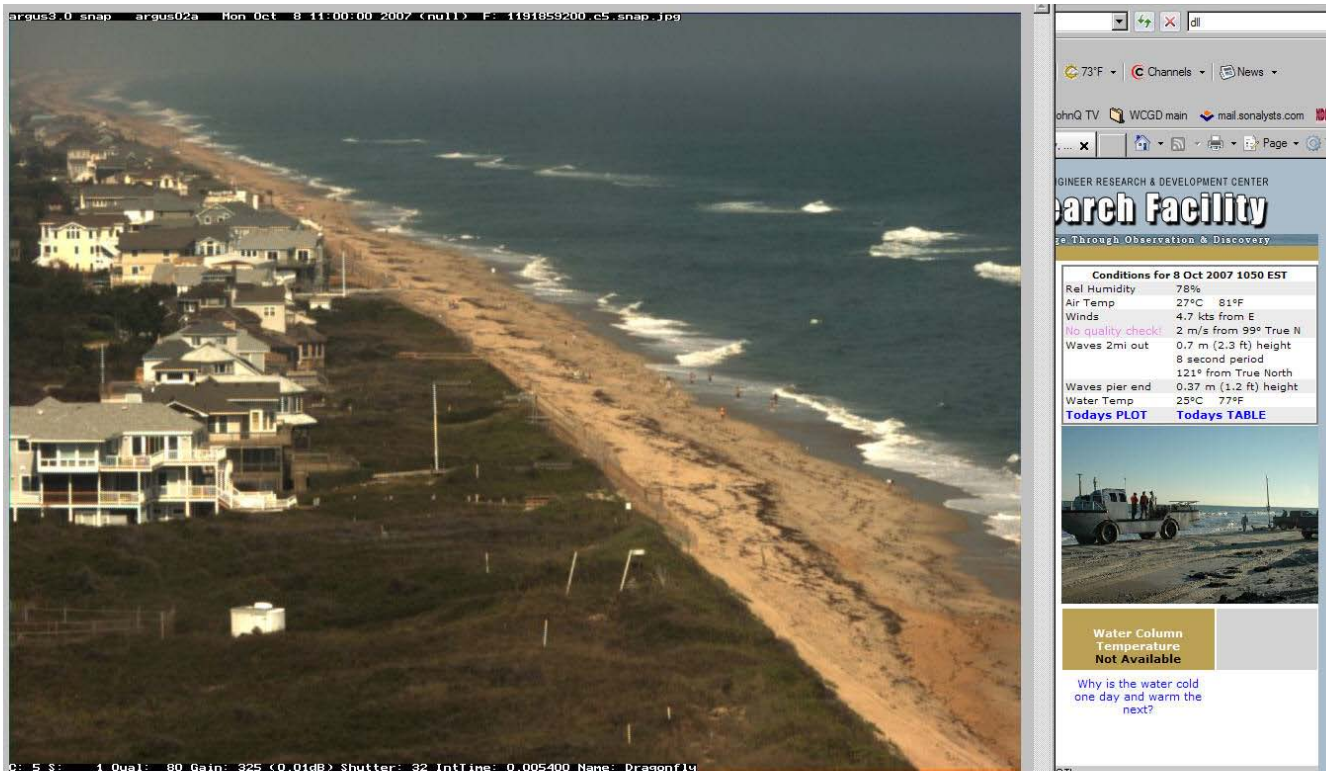
We investigated two primary approaches to modeling shallow water waves in real-time. The first approach used Navier-Stokes style fluid solvers, and the second approach was through investigation of wave parameterizations that matched observed conditions and are physics based.

Our selected solution was to develop a combination of two methods. We render only a small cross-section of the near-shore ocean surface as a thin field of about 100,000 particles and then use the parameterization method to calculate the position of each particle, with some modifications to allow for plunging breakers. The calculations are performed within a vertex shader to give maximum hardware performance upgrade.

Our set of parameterized equations represents the shallow water environment. Their use provides the benefit of easily running in real-time and allows us to model complex wave shapes including overturning and plunging. We looked at how the inputs to the parameterization would match with outputs from real-world observations and shallow water wave models such as SWAN.

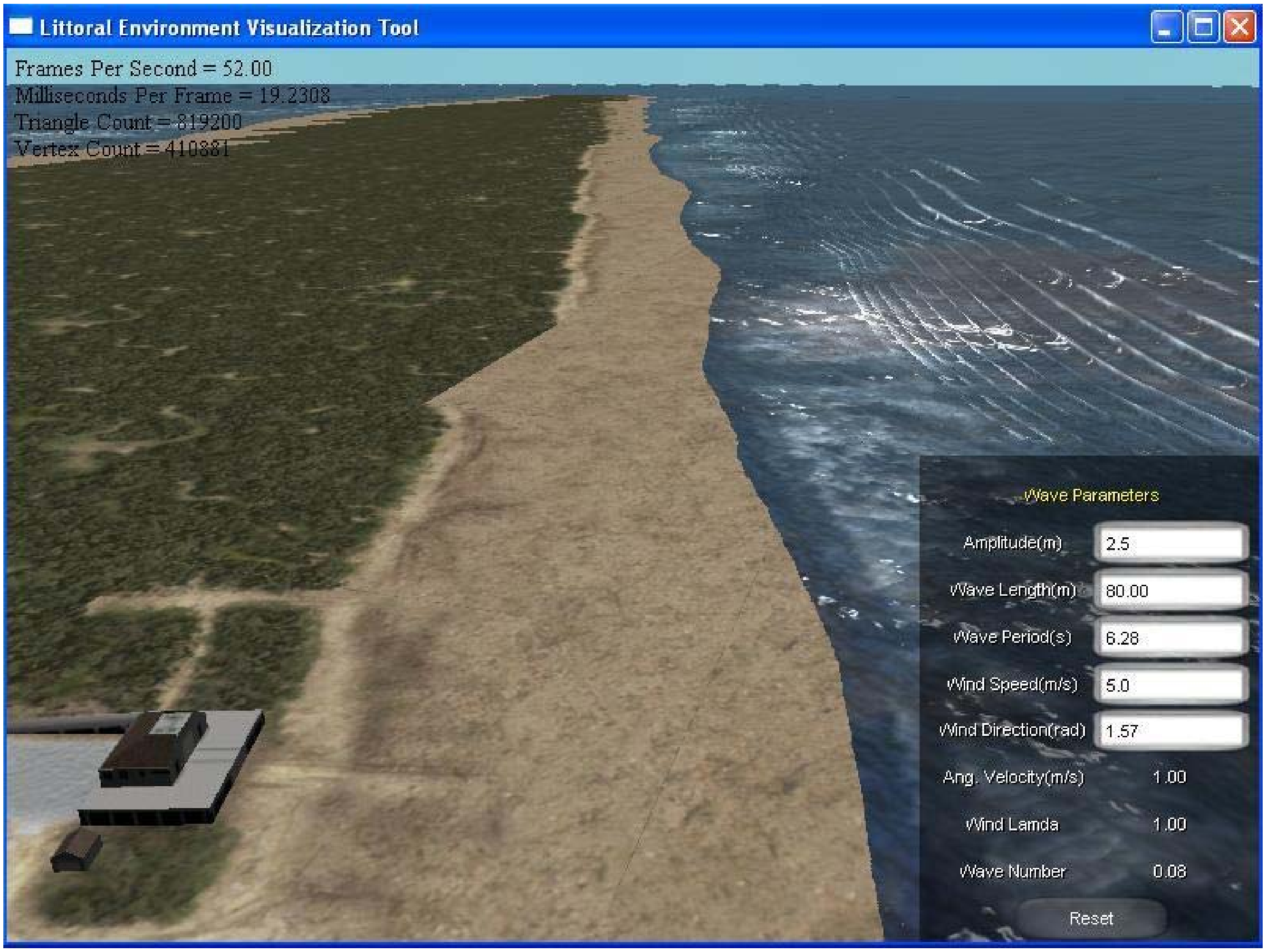
We ran the SWAN model, and read up on the documentation to study the types of outputs and how they could be used in our simulation. Several of the outputs we found to be of possible use for our simulation were: Significant wave height (HSIGN), Swell wave height (HSWELL), Mean wave direction (DIR), Peak wave direction (PDIR), and Associated wave periods (TM01/PER, TPS).

We decided to use the web site http://www.frf.usace.army.mil/frf.shtml as our source for obtaining input data into our model and for conducting our realism tests. Data available at this site: wind speed and direction, wave heights, periodicity and direction, and air and water temperature.



A Daily View of Shallow Water and Environmental Parameters from Web Site Selected for Realism Check

Our solution allows us to render fairly realistic looking waves that are driven by real physics based parameters; all while being animated in real time. We have implemented this solution into our commercial simulation which also required updating the graphics capability to make use of DirectX-9 technology. These updates are reflected in the proof of concept application that is currently being developed.



Preliminary Screen Shot from the Littoral Visualization Tool Proof of Concept Application

RESULTS

Our research has been largely directed towards determining a method we could implement in our commercial simulation that would allow realistic views of the near shore area and allow us to modify those views with environmental data in a near real-time manner. We considered simulating real-time shore waves through the use of a height field, or a matrix containing the height (or y-coordinate) of any vertex on the ocean surface, given the position of the vertex (its x and z-coordinates). This is the method of ocean surface simulation currently employed in our latest commercial micro-simulation. We found that, while this method of using height fields along with bump mapping textures provides very satisfying results for standing bodies of water or for deep water ocean surfaces it is not acceptable for our shallow water environment. This method requires every component in the height field to have only one height. It does not support the multiple heights that occur when simulating an object that can fold on top of itself (like a breaking wave).

We also attempted to simulate the motion of a breaking wave by using a set of algorithms parameterized for a number of given real-world inputs and then manipulating the vertices of the ocean surface mesh using the outputs from these algorithms. The inputs included: wave number (relative

separation of consecutive waves), angular velocity (rotational velocity of each particle in body of water), and wind lambda (scalar used to determine power of wind force acting on wave crest). While this method seemed promising, it alone was insufficient to generate the downward plunging crest of a breaking wave.

Another method involved the investigation of particle systems. We very quickly realized that simulating each individual particle in a body of water will give the most realistic visualization possible. However, the sheer number of calculations needed for this method makes calculating large particle bodies in real-time impossible. Even small bodies are very difficult to simulate in real-time, despite the latest advancements in graphical hardware. While there have been some published methods and models used to generate realistic looking waves, they are either not executable at an interactive frame rate (i.e. at least 30-40 fps), or are rendered primarily by look, without using real physics based inputs.

IMPACT/IMPLICATIONS

This research project will have immediate cost and time-saving benefits to the Navy. By providing near real-time visualization of the littoral environment and changes within that environment, the war-fighter will be able to more concisely estimate weather-related impacts on "Brown-Water" operations. Decision-making and Concept of Operations capabilities will be enhanced with a more perfect knowledge of environmental impacts on the Navy's ability to encompass a variety of operations. These operations can run the gamut from forward presence in peacetime, to crisis response in hot spots occurring near the coastlines of the world. Some decisions or CONOPS may include: selection of landing points for expeditionary forces, routes to take to arrive at those points, the types of equipment that might be used, or selection of time intervals for commencement of near-shore operations. The project will support a rapid understanding of the environment in identifying potential pitfalls and constraints provided to theater-level and on-scene commanders in life-threatening situations. This ability to more realistically visualize, on a near real-time basis, the environmental conditions that currently exist or are forecasted to exist will enhance the success of an operation.